

# **MID-UPPER ARM CIRCUMFERENCE: A SURROGATE FOR BODY MASS INDEX IN PREGNANT WOMEN?**

BY

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## **ABBREVIATIONS**

MOU midwife obstetric unit

BMI body mass index

MUAC mid upper arm circumference

CC calf circumference

WHO World Health Organisation

GSH Groote Schuur Hospital

NSH New Somerset Hospital

MMH Mowbray Maternity Hospital

SGA small for gestational age

IUGR intrauterine growth restriction

PPV positive predictive value

NPV negative predictive value

FP false positive

FN false negative

TP true positive

TN true negative

CI confidence intervals

EGG early gestational age group

LGG late gestational age group

SFH symphysis fundal height



## **ABSTRACT**

**Background:** Nutrition in pregnancy has important implications for both the mother and the fetus, hence the importance of an accurate assessment at the booking visit. Body mass index is currently the gold standard for measuring body fatness. However, pregnancy associated weight gain and oedema, as well as late booking in our population setting, questions the reliability of using the BMI to assess body fat or nutritional state in pregnancy. MUAC has been used for many decades in children under the age of five, to assess malnutrition. Many studies have shown a strong correlation between MUAC and BMI in the adult population. MUAC is a much simpler anthropometric measure to take as it eliminates the need for height charts, scales and calculations. One of the other main advantages of using MUAC is that there is minimal change in the MUAC during pregnancy, which may be a better indicator of prepregnancy body fat and nutrition.

**Objectives:** To assess if there is a correlation between the mid upper arm circumference and body mass index in pregnant woman booking in the Metro West area.

**Methods:** This was a cross sectional study of women booking at four MOUs in the Metro West area. Anthropometric measurements namely height, weight and MUAC were carried out on pregnant women booking for the first time in four midwives obstetrics units in Metro West area, Cape Town, South Africa. The participants were divided into two groups, early gestational age group for patients who booked less than twenty weeks, and a late gestational age group for those who booked more than twenty but less than thirty weeks.

**Results:** The results showed that there is a strong correlation between MUAC and BMI in pregnant women up to thirty weeks gestation. The correlation was

calculated at 0.92 for the entire group. A regression analysis showed that there is a statistical difference in the mathematical relationship between BMI and MUAC, between the two groups (EGG and LGG). MUAC of 27cm and 31cm had sensitivities and specificities of more than 80% for identifying pregnant women as overweight and obese respectively.

**Conclusion:** The MUAC correlates strongly with BMI in pregnancy up to a gestation of thirty weeks in women in Metro West maternity services. In a low resource settings, the simpler MUAC measurement to assess nutritional status and screen women who are at risk for potential adverse pregnancy outcomes could reliably be substituted for BMI estimation

## **INTRODUCTION**

For decades the mid upper arm circumference (MUAC) measurement has been used in children as a measure of nutrition. Body mass index (BMI), on the other hand, has been used in adults as a measure of body weight and of under nutrition. Body mass index is calculated by dividing weight in kilograms by height in metres squared. MUAC is measured using a standard tape measure, similar to the one used for symphysis fundal height, midway between the acromion process of the shoulder joint and the olecranon of the elbow, usually of the left arm.

In pregnancy, nutritional assessment is problematic given the serial weight gain and oedema that develops particularly after the second trimester. Measurement of weight alone therefore is of limited value. BMI measured in the first trimester or early second trimester is the conventional measure, since it takes account of maternal height, despite also having limitations.

There are many potential advantages to using the MUAC; accurate scales for weight and height measurements are not needed, and no calculation for BMI needs to be done. The other main advantage is that there is minimal change in MUAC during pregnancy. Many patients in public maternity care settings in South Africa book late and the subsequent BMI calculated is an inaccurate assessment of nutritional state. The MUAC would be much more useful in this setting of patients who book late and where there are resources constraints.

In South Africa the MUAC measurement has recently been incorporated into the Maternity Case Record nationally and in the Western Cape after it was reviewed by the nutritional directorate. The current South African guidelines for maternity care stipulates the following regarding the use of MUAC<sup>1</sup>:

A MUAC  $\geq 33$ cm:

- Suggests obesity
- Associated with increased risk of pre eclampsia and maternal diabetes
- Associated with an increase risk of delivery of a larger than normal infant
- Indicates that blood pressure reading might be overestimated with a normal adult-sized cuff

A MUAC  $\leq 23$ cm:

- Suggests undernutrition or a chronic wasting illness
- Associated with delivery of a smaller than normal infant

Currently it is recommended that if an abnormal MUAC above 33cm is found that it requires vigilance regarding SFH growth, hypertension, screening for diabetes, use of the appropriate BP cuff size and referral to the appropriate level of care. As for MUAC of  $\leq 23$ cm requires particular attention to SFH growth and possible referral for nutritional support if indicated<sup>1</sup>.

In the Western Cape the BMI is used as a referral criteria from MOU for hospital care. Patients with BMI of  $\geq 30$  are referred to district hospital,  $\geq 40$  but  $< 50$  are referred to a regional hospital, and those with a BMI of  $\geq 50$  are referred to a tertiary hospital for care<sup>2</sup>.

The question posed in this study is whether the mid upper arm circumference in pregnancy correlates with BMI in our maternity care setting, and thus could be a simpler screening tool to identify patients who are not only malnourished but also those who are obese. Both under nutrition and obesity are associated with an increased risk of perinatal and maternal mortality and morbidity. If MUAC is found to correlate well with BMI, it could possibly replace it as a measure of nutritional status as well as obesity in pregnancy.

## **Literature review**

In children measuring the circumference of the arm has been considered a useful indicator of nutritional status. Unlike body weight it is relatively age independent. Children with a MUAC measuring generally 12.5cm or 13cm are at risk of moderate under nutrition in the under-five age group<sup>3</sup>.

Measuring the mid upper arm circumference (MUAC) requires minimal equipment and has been found to predict morbidity and mortality as accurately as deficits in weight. James et al looked at the usefulness of MUAC as a substitute for BMI in chronic energy deficiency in adults in third world countries. He found that there was a high correlation between BMI and MUAC, and that MUAC values of 22cm and 23cm for women and men respectively, are useful cut offs for simple screening for poor nutritional status<sup>4</sup>.

Collins et al studied the use of MUAC and body mass index (BMI) in severely malnourished adults during famine. He found a strong correlation between BMI and MUAC ( $r=0.88$ ). MUAC may be better suited to screen admissions to adult feeding centres. During famine, height and weight measurements required to calculate BMI are time consuming and difficult to obtain from severely malnourished people who can hardly sit up unassisted. The other pitfall with using BMI is that oedema associated with famine can confound the BMI calculation, similar to the oedema of pregnancy<sup>5</sup>.

In pregnancy, a MUAC of under 23 cms should raise concern about possible risk of under nutrition, and antenatal care should include observance regarding SFH and possible IUGR, as well as providing nutritional interventions. If MUAC is over 33cms, this should raise concern for the increased risks of gestational diabetes, hypertension, fetal macrosomia, obstructed labour and the need for a larger sphygmomanometer cuff for blood pressure readings.

Mid-upper arm circumference is often used to screen for underweight or malnourished individuals, but no universal cut off points have been identified. Various national nutritional protocols use the following MUAC cut off values for inclusion of pregnant women into nutritional programmes: MUAC <18.5 cm (Zimbabwe 2008), <21.0 cm (Burkina Faso, Burundi 2002, DRC 2008, Guinea 2005, Madagascar 2007, Malawi 2007, Mali 2007, Nigeria 2006, Senegal 2008), <22.0 cm (Mozambique 2008), <22.5 cm (Zambia 2009), <23.0 cm (Indonesia 1996) and ≤23 cm (Sri Lanka 2006). The review done by Ververs et al has recommended a conservative cut off of <23cm for moderate malnutrition in both African and Asian countries<sup>6</sup>.

There are only a few studies looking at MUAC and mortality, as well as other health measures. The paucity of data has rendered WHO unable to establish standard cut offs for the use of MUAC. Table 1 displays the MUAC cut offs suggested by the Food and Nutrition Technical Assistance (FANTA) consortium in their 2013 guide<sup>7</sup>.

Table 1. MUAC cut offs to classify nutritional status in adults<sup>7</sup>.

<b>Non-pregnant</b>	<b>Pregnant/postpartum</b>	<b>Nutritional status</b>
< 190mm	<190mm	Severe acute malnutrition
≥190 < 220mm	≥190 <230mm	Moderate malnutrition
≥220mm	≥230mm <330mm	Normal

Kruger et al reviewed maternal anthropometry and pregnancy outcomes, and proposed some criteria for monitoring pregnancy weight gain in outpatient clinics in South Africa. He proposed that pregnant women with a weight of <50kg or a height of <145cm or a MUAC of <22cm should be referred for

nutritional care. He also advised that pregnant women who gain <1 kg per month or > 3kg per month should be referred to a dietician<sup>8</sup>.

BMI was first described by a Belgian mathematician, Adolphe Quetelet in 1835. It is the most commonly used measure of body fat. The World Health Organisation (WHO) classifies body fat using body mass index and subdivides it into the following categories: underweight, normal weight, overweight, obese and morbidly obese<sup>9</sup> (see Table 2).

Table2. WHO classification of body fat<sup>9</sup>.

<b>BMI (kg/m<sup>2</sup>)</b>	<b>Classification</b>
<18.5	Underweight
18.5-24.9	Normal weight
25-29.9	Overweight
30-39.9	Obese
≥40	Morbidly obese

Despite BMI being the most common or standard method of assessing nutritional state and obesity there have been many reviews looking at the pitfalls of using BMI.

A review done by Bhurosy highlights some of the concerns. BMI and its relationship to body fat percentage are affected by environmental factors such as exercise, as well as age, gender and ethnicity. When similar BMIs were compared between old and young subjects, they found a higher fat percentage in the older group. Ethnicity also plays a significant role. Studies on the populations from Hong Kong and Singapore revealed an increased risk for diabetes and cardiovascular disease at a lower BMI. Therefore distinct Asian

cut-offs for overweight based on BMI of 23- 24.9 kg/m<sup>2</sup> is already being utilised to assess morbidity in these populations. It is well known that women have higher prevalence of obesity as compared to men. Fat distribution is also different between males and females<sup>10</sup>.

Nutrition has progressively become an important factor in pregnancy because of its association with increased risk of adverse pregnancy outcomes.

Underweight women are at increased risk for having small for gestational age and IUGR babies, and are also at risk of preterm delivery however to a lesser degree<sup>11</sup>.

Under nutrition in pregnancy does not only have the short term consequences of low birth weight, intrauterine growth restriction and preterm labour. The stressful environment in utero for the fetus also has long term consequences for the offspring in adult life. Low birth weight is associated with an increased risk of chronic diseases and obesity in adulthood<sup>11</sup>.

The Fetal origin hypothesis has been proposed by Barker. He proposed that a fetus exposed to poor nutrition in utero undergo adaptations which permanently change their physiology and metabolism. These programmed changes then predispose them to diseases in later life specifically coronary heart disease, and the associated diseases diabetes, hypertension and stroke. Studies in Hertfordshire, Sheffield and the USA have shown an increase in coronary heart disease in adult years of infants born at the lower birth weight range. In India, a study has shown the prevalence of coronary heart disease falls from 18% to 4% when comparing adults who were born at 2.5kg versus more than 3.2kg<sup>12</sup>.

Roseboom et al studied people born at the time of the Dutch famine. They were found to have more coronary heart disease, more atherogenic lipid



profiles, changes in clotting profile, increase in obesity as well as an increased stress response. Female offspring exposed to famine during early gestation also had an increased risk of breast cancer. The most vulnerable period of the pregnancy is during early gestation. Interestingly, a fetus exposed to famine or under nutrition during early pregnancy, still had the adverse effects of an increased risk of chronic diseases later in life despite being born at normal weight<sup>13</sup>.

Some older studies found an increased maternal risk in the under nourished pregnant woman. Verhoeff et al and Charles et al both found an association with a low MUAC and the increased risk for anaemia. Verhoeff et al did a study on over 4000 women at an antenatal care facility in Malawi. He found that pregnant females with a MUAC measurement of 23cm or below were at increased risk for a moderately severe anaemia<sup>14</sup>. Charles et al looked at predictors of anaemia in pregnant women in Jamaica and too found that a BMI of under 25 kg/m<sup>2</sup>, MUAC under 25cms, and fewer than four antenatal clinic visits had a statistically significant association with anaemia. Anaemia is regarded as a major risk factor for adverse pregnancy outcome as well as increased maternal risk<sup>15</sup>.

Libombo et al did a case referent study in Maputo looking at the risk factors for puerperal endometritis and myometritis. They looked at 51 women diagnosed with puerperal endo-myometritis and compared them to 51 healthy matched controls. Not surprisingly previous stillbirth and previous low birth weight was significantly higher amongst cases. The cases also differed significantly when compared to healthy controls, with greater numbers having body mass index less than 22.5kg/m<sup>2</sup> (OR 3.41), mid upper arm circumference less than 25cm (OR 2.66) and haemoglobin level less than 10g/dl (OR 3.12)<sup>16</sup>.

Christian et al did a prospective study in rural Nepal of almost 26 000 pregnancies. The study examined the risk factors of mortality related to pregnancy for the first year post partum. Information on socio-economic status, MUAC, diet history, illness, work, substance abuse and previous pregnancy history were collected early-mid gestation. They found that maternal age ( $\geq 35$  yrs) parity (nulliparous), MUAC ( $\leq 21$  cm), diet (Vitamin A deficiency) and illness were associated with an increased risk of death. Mortality risk during pregnancy and the first year postpartum was 25% lower with each centimetre increase in MUAC at the time of pregnancy enrolment. A thinner arm is reflective of wasted lean muscle mass, and it is well known to be an increased risk of mortality in children<sup>17</sup>.

Ververs et al did a review to look at which anthropometric indicators best identify a pregnant woman as acutely malnourished and predicts adverse birth outcomes in a humanitarian context. After reviewing MUAC, BMI, maternal weight for gestational age, maternal height and maternal weight gain, they concluded that MUAC is the most reliable indicator of risk of LBW in a humanitarian context. As well, they suggested that a cut-off  $< 23$  cm is a strong indicator for identifying a pregnant woman at high risk of LBW, and should also be a cut off to enrol women into a nutritional support programme<sup>6</sup>.

The risk factors associated with low birth weight go far beyond malnutrition or maternal nutrition. It includes socioeconomic factors, smoking history, employment, level of education, partner support, HIV status, and many others. So one has to question whether providing nutritional support programmes as an intervention actually makes a difference or not, as it only addresses one potential risk factor associated with LBW.

A randomised controlled trial looking at maternal dietary supplementation and its effects on birth weight and perinatal mortality was done in rural Gambia by Ceesay M et al. The outcome of the trial showed a significant increase in pregnancy weight gain as well as an increase in birth weight more so during the hungry season as compared to the harvesting season. There was also a significant reduction in stillbirths as well as early neonatal deaths, however late perinatal deaths were unaffected<sup>18</sup>.

Improved maternal nutrition has been associated with an increase in fetal growth and reduction in adverse outcomes in developing countries, and in populations with nutrient deficiencies, but not in well nourished population. Villar et al raised the concerns as to what effect a few months of increased nutrition would have in pregnant women with a background of two to three decades of chronic under nutrition. They found a significant increase in birth weight after nutritional supplementation was provided over 2 consecutive pregnancies as well as the interim lactation period<sup>19</sup>.

A review done by Bhutta et al looked at community based interventions for improving perinatal and neonatal mortality in developing countries. When they reviewed protein energy supplementation for malnourished women during pregnancy the overwhelming evidence came from the Gambian study. Supplementation generally resulted in increased birth weight and or a reduction in the LBW rate. Overall, however, balanced energy-protein supplementation seems to have only a modest effect on mean birth weight (weighted mean difference: 25 g; CI: -4 to 55 g) but a more substantial effect on reducing IUGR (OR: 0.68; CI: 0.57– 0.80). The Gambian study increased birth weight by a substantial 136g. However the supplement given to these women were significantly higher in energy content compared to other studies, 3780 kJ per day, as compared with an 840- to 1050-kJ-per day in most of the other

trials. The review concluded by advising that, the reductions in stillbirths and improved perinatal mortality associated with supplementation, was convincing evidence to implement a protein energy supplementation programmes to be targeted towards at risk populations. However, the authors acknowledged that it may be a rather costly intervention<sup>20</sup>.

A Cochrane review concluded that balanced energy protein supplementation reduced the incidence of SGA by 32% and risk of stillbirths by 45%. A recent and updated meta-analysis showed that balanced energy protein supplementation increased birth weight by 73 g (95% CI 30–117) and reduced the risk of SGA by 34%, with more pronounced effects in malnourished women<sup>21</sup>.

Obesity on the other hand has shown an alarming increase worldwide, including in South Africa. A study done by Puoane et al, found that 56.6% of women over the age of 15yrs were overweight or obese in South Africa<sup>22</sup>. Obesity has increased risks for both the mother and fetus. Maternal risks are an increased risk for gestational diabetes and hypertension, caesarean section, veno-thromboembolism, postpartum haemorrhage and sepsis. For the fetus, there is an increased risk of miscarriage, macrosomia, stillbirth and neural tube defects<sup>23</sup>.

A prospective study done in South Africa by Nieuwoudt et al looked at a comparison of pregnancy outcomes between morbidly obese and super-obese women. They found a significantly higher incidence of pre eclampsia, IUGR, longer duration of procedures, surgical complications and longer hospital stay in the super-obese category compared to morbidly obese women<sup>24</sup>.

Okereke et al looked at anthropometric indices for diagnosing obesity in pregnancy in a cross sectional study in Nigeria. He found that MUAC of 33cm

and a calf circumference (CC) of 39cm may be a reliable cut off for diagnosing obesity in pregnant women in Nigeria. A strong correlation between BMI and MUAC was also evident with a correlation coefficient of 0.87. A stronger correlation between MUAC and BMI was identified as compared to CC, with MUAC having not only a better correlation but a higher sensitivity (76%) and specificity (91%) for obesity than CC. In this particular study there was no significant difference in the MUAC measurements across the 3 trimesters, which suggests that it is a measurement independent of gestation and age <sup>25</sup>.

A systematic review was done looking at the effects of interventions in pregnancy on maternal weight and obstetric outcomes. It looked at 3 categories of intervention, namely diet, physical intervention and a mixed approach. Most participants were either overweight or obese. The dietary intervention was associated with greatest reduction in weight gain in pregnancy. This resulted in a significant reduction in preeclampsia. An overall decrease in trend towards gestational hypertension and diabetes, preterm birth and intrauterine fetal death compared with the control group however was not clinically significant<sup>26</sup>.

Mohamed et al looked at risk factors for pre eclampsia among Zimbabwean women, specifically looking at MUAC and other anthropometric measures of obesity. Linear trends displayed an increased risk of PET with an increasing MUAC, weight and BMI. Females with a MUAC of 28-39cm were 4.4 times more likely to have their pregnancies complicated by PET than females with a MUAC between 21-23cm<sup>27</sup>.

Ogbonna also looked at maternal MUAC and other anthropometric measures of adiposity in relation to infant birth size among Zimbabwean women. A cross sectional study of pregnant women was done. They measured BMI, height,

weight and MUAC in the immediate postpartum period and looked at its relation to birth weight. MUAC was strongly related to the four infant size indices measured. Each unit increase in the MUAC resulted in a 36.1g increase in infant birth weight. As the MUAC increased from 25 to 26cm and over 27cm, pregnant women were 62% and 60% less likely to have a LBW infant. MUAC was more strongly related with infant birth weight, head circumference and length than any of the other anthropometric measures studied<sup>28</sup>.

Interestingly Hediger et al looked at the value of changes in the MUAC in late pregnancy to predict fetal growth in twins. They found that a large decrease of MUAC at the end of a twin pregnancy is associated with a reduced fetal growth. This result had a high specificity of 94.3% but a very low sensitivity for poor fetal growth of only 9.1%. They also found that BMI had a strong correlation to pre-pregnancy BMI. The females who had the significant decrease in MUAC were significantly heavier before pregnancy but gained less weight in pregnancy on average<sup>29</sup>.

Khadivzadeh looked at MUAC and calf circumference as indicators of nutritional status in women of reproductive age in Iran. They too found that BMI correlated strongly with MUAC and CC. The cut off of 24cm was used to detect underweight females, it had a sensitivity of 93.6% and a specificity of 83.9%. Only 6.4% of malnourished females were undetected. It had a PPV of 60.6% and a NPV of 98.1%. Different countries use different cut offs, in Nigeria a cut off of 23cm for detecting malnourished females were proposed. A MUAC cut off of 30.5cm was used for detecting overweight females and a BMI of over 29 kg/m<sup>2</sup> as the reference value. There were 88.8% of women with a BMI over 29 kg/m<sup>2</sup> who had a MUAC over 30.5cms. There were only 10.2 % of females who were not identified as being overweight, with a specificity of 94.5%. MUAC of 30.5cm had a PPV of 70.9% and a NPV of 98.3% for detecting

women who had a BMI more than 29kg/m<sup>2</sup>. They also proposed that in countries where changes of MUAC in pregnancy are negligible, the MUAC can then be used to calculate the pre-pregnancy BMI<sup>30</sup>.

Nutrition in pregnancy and especially acceptable weight gain in pregnancy has been debated many times over the last century. Over the last 50 years, recommendations for pregnancy weight gain have been highly controversial in the United States. During the first half of the century, American obstetricians restricted weight gain during pregnancy to prevent toxemia, difficult births, and maternal obesity<sup>31</sup>.

*Williams' Obstetrics*, a prominent American textbook, stated in 1966 that "Excessive weight gain in pregnancy is highly undesirable for several reasons; it is essential to curtail the increment in gain to 25lb (12.5 kg) at most or preferably 15lb (6.8 kg). The experienced obstetrician is convinced of the complications, both major and minor, caused by excessive weight gain in pregnancy. Although restriction of the gain in weight to 20lb (9.1 kg) may be difficult in many cases, requiring careful dietary control and discipline, it is a highly desirable objective"<sup>31</sup>.

In the 1960s, the experts started challenging the practice of restricting weight gain in pregnancy, when they recognized that the relatively high rates of infant mortality, disability, and mental retardation seen in the United States were a result of low birth weight. This theory was confirmed in the 1970s by the National Academy of Sciences<sup>31</sup>.

The Institute of Medicine then devised guidelines in 1990 for the recommended weight gain during pregnancy and revised them again in 2009. Their recommendations were divided into the known BMI categories, of underweight, normal, overweight, obese. One of the criticisms of the guideline is that it does not further subdivide the class of obesity into class 1, 2 and 3<sup>32</sup>.

Table 3. Recommended weight gain during pregnancy by Institute of Medicine 2009<sup>32</sup>.

<b>Prepregnancy weight category</b>	<b>Body mass index</b>	<b>Recommended range of total weigh lbs (kilograms)</b>	<b>Recommended rate of weight gain in the 2<sup>nd</sup> and 3<sup>rd</sup> trimesters (mean range lbs/week)</b>
Underweight	<18.5	28-40 (12.5-18kg )	1( 1-1.3)
Normal weight	18.6- 24.9	25-35 (11.5-16kg)	1 ( 0.8-1)
Overweight	25-29.9	15-25 (7.0-11.5kg)	0.6(0.5-0.7)
Obese	>30	11-20 (5-9kg)	0.5(0.4-0.6)

On the contrary a study done by Bhattacharya et al assessing the effect of BMI on pregnancy outcomes in nulliparous women delivering singleton babies found that the undernourished female is at the lowest risk for adverse pregnancy outcomes when compared to those with normal and high BMI. Apart from the slightly increased risk of having a baby with low birth weight, this group of women seem to have the lowest rates of pregnancy or labour complications<sup>33</sup>.

The above finding was supported by a study done by Sebire et al, who performed a population based study in London. He too found antenatal anaemia, preterm delivery and low birth weight more frequent in the underweight group. However the prevalence of gestational diabetes, preeclampsia, post-partum haemorrhage, induction of labour and caesarean section significantly lower in the underweight group, and interestingly there



was no difference in postpartum complications such as infectious morbidity between the groups<sup>34</sup>.

Cnattingius S et al assessed the associations between prepregnancy weight and the risk of adverse pregnancy outcomes in a population based cohort in Sweden. Their results were in keeping with the above studies showing an increased risk of late fetal death and preeclampsia in obese women, as compared to lean and normal weight women, and an increased risk of delivering a SGA baby in lean women. They even went as far as suggesting that pregnancies among lean women should be regarded as low rather than high risk, and that the advice for lean women to gain weight prior to conception was not justifiable<sup>35</sup>.

Pre-pregnancy BMI and gestational weight gain are the 2 most used indicators closely related to neonatal birth weight. However in developing countries prepregnancy BMI is frequently unknown and therefore total weight gain can often not be calculated.

In pregnancy weight gain can be also be due to clinical oedema, therefore rendering MUAC or skinfold measurements better alternative parameters to use for nutritional assessment. The MUAC measurement undergoes minimal change during pregnancy. A study done by Lopez et al in Argentina looked at the changes in MUAC during pregnancy. It showed an increase of 1.7cm from the first trimester to 28 weeks, and from 28 weeks to term it only increased a further 0.6cm<sup>36</sup>.

MUAC and maternal weight were significantly associated. The correlation coefficient was strongest in the 1<sup>st</sup> trimester ( $r=0.735$ ,  $P<0.001$ ) with a decrease throughout pregnancy ( $r=0.718$  @28w, and  $r=0.638$  @ 36w  $P<0.001$ ).

The association between the increase in MUAC and total weight gain was weaker ( $r=0.165$ ,  $P<0.001$ )<sup>36</sup>.

Another study done in Mozambique looked at the value of MUAC in pregnancy and found that it is strongly associated to estimated pre-pregnancy weight ( $P<0.0001$ ), as well as mid-upper arm muscle circumference ( $P<0.002$ ). This indicates that MUAC is a useful parameter for assessing nutritional state of pregnant women especially in developing countries or in areas of low resource setting<sup>37</sup>.

S M Cooley et al did a study in Ireland looking at the relationship between BMI and MUAC in the pregnant population. They found that BMI was positively correlated with mid arm circumference ( $r=0.836$ ;  $p<0.01$ ). This correlation persisted across all categories of BMI. They also noted that BMI could be calculated from the MUAC using the simple mathematical equation  $BMI = MUAC^2 / 4$ . When the morbidly obese was excluded from the sample of patients the BMI could be calculated for 78% of the cases from MUAC. When they tried to determine a cut-off point for the overweight patient they found that a MUAC of 27cm had a detection rate for overweight of 75% with a false positive rate of 15%<sup>38</sup>.

Ricalde et al looked at MUAC and its relation to birth weight. A small sample size of 92 patients was followed through the pregnancy in a hospital in Brazil. They measured MUAC at 3 different points in the pregnancy and found that there was no significant variation of the MUAC during pregnancy. Their results showed a positive correlation between MUAC, pre-pregnancy weight and birth weight and not surprisingly a strong correlation between gestational age and birth weight. They proposed that, because of the strong correlation between pre-pregnancy weight and MUAC, the MUAC could be used instead of it to

screen for women at risk of adverse pregnancy outcome or for those who book late in pregnancy<sup>39</sup>.

## **Aims and objectives**

To assess if there is a correlation between BMI and MUAC in the pregnant population of patients booking at midwife obstetric units (MOU) in the Metro West maternity service.

## **Methodology**

### **Study Design**

This is a cross-sectional observational study of women who booked at the midwife obstetric units at Retreat, Gugulethu, Hanover Park and Mitchells Plain.

### **Study Setting**

The obstetric service in the Metro West area is comprised of facilities which are divided into primary care, district, secondary and tertiary levels of care. The Midwife Obstetric Units, are the primary facilities run by trained midwives, servicing the low risk obstetric cases. Midwives at the various MOU facilities then refers to the above centres as needed. The secondary level facilities are Mowbray Maternity Hospital (MMH) and New Somerset Hospital (NSH). The tertiary referral centre is Groote Schuur Hospital (GSH). Patients are usually referred to the appropriate facilities according to their risk status, in accordance with various referral criteria and protocols.

The Gugulethu, Hanover Park, and Retreat MOUs refer complicated patients to MMH. Vanguard MOU refers to NSH. Mitchells Plain MOU refer district level cases to the Mitchells Plain District hospital, and all their secondary level cases

to MMH. Of note, most patients' book via the MOU facility, so despite collecting data at the low risk facility in this current study, we still got a variety of BMI and MUAC measurements from high risk women before they were referred onwards for further care. After booking, patients with a BMI  $\geq 30$  are referred to district hospital,  $\geq 40$  but  $< 50$  are referred to a regional hospital (MMH or NSH), and those with a BMI of  $\geq 50$  are referred to the tertiary hospital (GSH) for care.

We collected our data from patients who booked at the low risk obstetric MOU facilities namely Retreat, Gugulethu, Hanover Park and Mitchell's plain. The population from these areas were of coloured and black origin, with a low socio-economic status. The socioeconomic status, living conditions and ethnicity of study subjects was not captured in this study. Below an overview of the various townships are described.

Gugulethu MOU services the Gugulethu high density suburb which is a large formal and informal settlement area on the Cape flats, mainly inhabited by a Xhosa speaking, black population. A census done in 2011 showed it had a population of 98 468<sup>40</sup>.

Retreat drains all of the surrounding area plus an informal settlement in Hout Bay called Masiphumulele. This population comprises of a majority coloured population with English as a first language for 59% of its residents, and Afrikaans for 34.8%. According to the census done in 2011 its population was 25745<sup>41</sup>. Masiphumelele an informal settlement in Hout Bay also drains to Retreat MOU; it comprises 89% black Africans, and Xhosa is being spoken by 58.1 %. Many migrants from Zimbabwe, Malawi and Mozambique also reside in the area. Looking at the various language percentages spoken in the 2011 census, it listed 29.9% for "other" languages most likely displaying the

proportion of foreign migrants. In the 2011 census its population was estimated at 15969<sup>42</sup>.

Hanover Park and Mitchells Plain are both coloured communities on the Cape Flats. Mitchells Plain is one of the largest coloured townships, housing a population of 310 485 according to the 2011 census. It was erected for middle income families residing in formal housing. However over the years a number of informal settlements have arisen. It comprises 90% coloured population, half using English as their first language, and the other half using Afrikaans. Unfortunately this community as many others on the Cape Flats is has a serious problem of gangsterism and drugs<sup>43</sup>. Hanover Park is a smaller community comprising of 34625 according to the 2011 census. More than 95% of its population is coloured and Afrikaans speaking (70.7%)<sup>44</sup>.

### **Study subjects**

All pregnant women booking at the study MOUs before 30 weeks gestation were eligible for the study.

Exclusion criteria were:

- 1) Patients younger than 18yrs of age
- 2) Gestational age of >30 weeks at the booking visit
- 3) Twin gestation

### **Data collection**

When patients book at an antenatal facility the patients history is taken, she is examined and a host of baseline measurements are done, viz. blood pressure,

weight, height, urinalysis, and MUAC. The booking midwife would then enter all this information onto the booking card within the maternity case record.

Informed consent was obtained from all participants, and an information leaflet was provided in English, Afrikaans and Xhosa. For the purpose of this study, the principal investigator did all the weight measurements on a single scale between the MOUs, as well as measured all the MUAC measurements of the participants. The height measurements were taken by the nursing staff. Depending on the availability of an ultrasound machine on the days of data collection, gestational age was assessed by last menstrual period, by an ultrasound or by booking palpation using the symphysis fundal height. All the data collected viz. maternal height, maternal weight, gestational age, parity, maternal age and MUAC was entered onto a purpose designed spread sheet (see Appendix two).

### **Sample size**

The sample size was calculated using the available literature. The calculation is based on the assumption that there will be a correlation of 60% between BMI and MUAC in patients above 20 weeks gestation (late gestational group- LGG), and an 80% correlation in patients less than 20 weeks gestation (early gestational group- EGG). A 2-sided significance level of 95 was used and a power of 80%. A ratio of 1:1 was used. A sample size of 164 was calculated<sup>45</sup>.

**Table 4. Sample size calculations**

	<b>Kelsey</b>	<b>Fleiss</b>	<b>Fleiss with CC</b>
Sample Size – Exposed	83	82	91
Sample Size- Non-exposed	83	82	91
Total sample size:	166	164	182

## **Statistical Analysis**

The data collected was analysed with the help of a statistician. Data was analysed using Stata Version 13 statistical package. The data is divided into descriptive, continuous and categorical variables. Descriptive data are presented in graphs and tables. For the correlations the data is presented in a scatter plot and a Pearson correlation coefficient was used for analysis. A p-value  $<0.05$  was used to indicate the level of statistical significance. A linear regression model was done to assess the relationship between MUAC and BMI, and to assess MUAC cut offs.

## **Ethics**

Permission for this study was sought from the Department of Obstetrics and Gynaecology Research Committee, the PGWC health research committee as well as the University of Cape Town Ethics Committee prior to data collection. Individual informed consent was obtained from all subjects. All individual patient identifiers were kept confidential and data kept securely.

## **Results**

A total of 164 participants were included in the study as stipulated by our sample size calculation. There were 82 participants more than 20 weeks gestation but less than 30 weeks; this group was referred to as the late gestational group (LGG), and 82 patients less than 20 weeks gestation referred to as the early gestational group (EGG). The data was collected over the period of October 16<sup>th</sup> -31<sup>st</sup> 2014 from participants booking at Mitchell's Plain, Hanover Park, Retreat and Gugulethu Midwives Obstetric Units.

Table 5 describes demographic details of the study population.

Table 5. Demographic details of study population

<u>Number of participants from MOU</u>	N=164
Gugulethu	27
Hanover Park	10
Retreat	49
Mitchells Plain	78
<u>Age categories</u>	
Mean age (SD)	27.09yrs ( $\pm 5.56$ )
18-23 yrs(%)	N=52 (31.7%)
24-29yrs	N=62(37.8%)
30-35yrs	N=36(21.9%)
36-41yrs	N=13(7.92%)
42-47yrs	N=1(0.6%)
<u>Parity</u>	N
Primiparous (%)	46 (28%)
Multiparous (%)	118 (71.9%)
Mean weight (SD)	72.5kg( $\pm 17.7$ kg)
Mean height (SD)	159.8cm ( $\pm 6.2$ cms)

There were 49 participants from Retreat MOU, 78 from Mitchells Plain, 27 from Gugulethu and 10 from Hanover Park. Socioeconomic information was not obtained from the participants. However all the participants were either of black or coloured origin, and the areas where the data was collected from were communities with low socioeconomic status. The mean maternal age of the participants was  $27.09 \pm 5.56$  years with an age range of 18-44 years. There was a mean weight of  $72.5 \text{ kg} \pm 17.7 \text{ kg}$  and a mean height of  $159.8 \pm 6.2 \text{ cm}$ . A



total of 71.9 % of the participants were multiparous, and 28% were primiparous.

Figure 1. Gestational age distribution

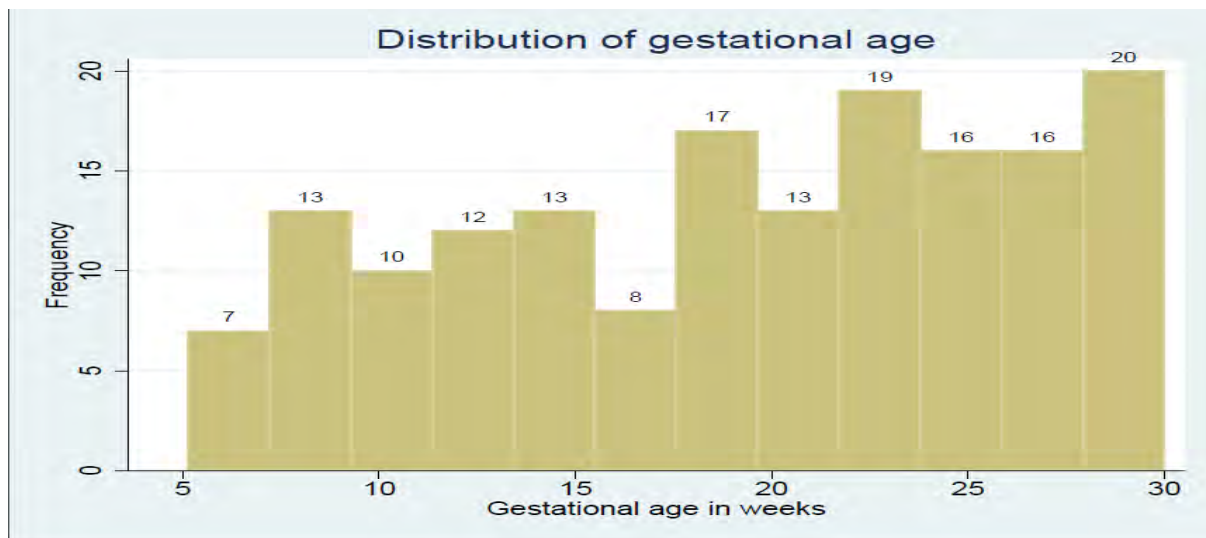


Figure 1 demonstrates the distribution of gestational age of the sampled population. The mean gestational age was calculated as 19 weeks  $\pm$  6.99

Figure 2. Distribution of Body Mass Index

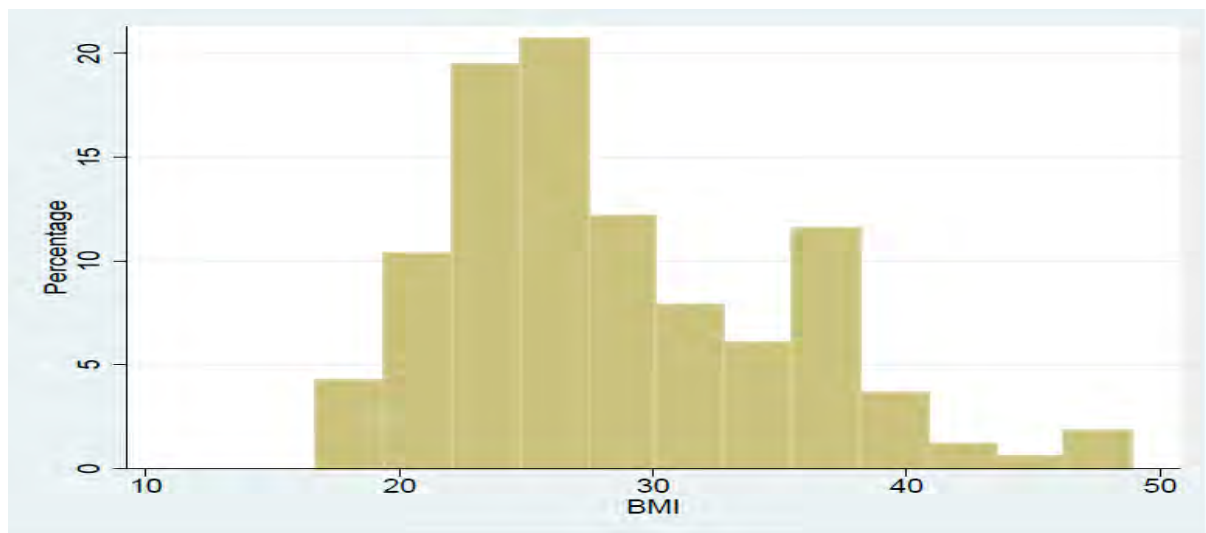
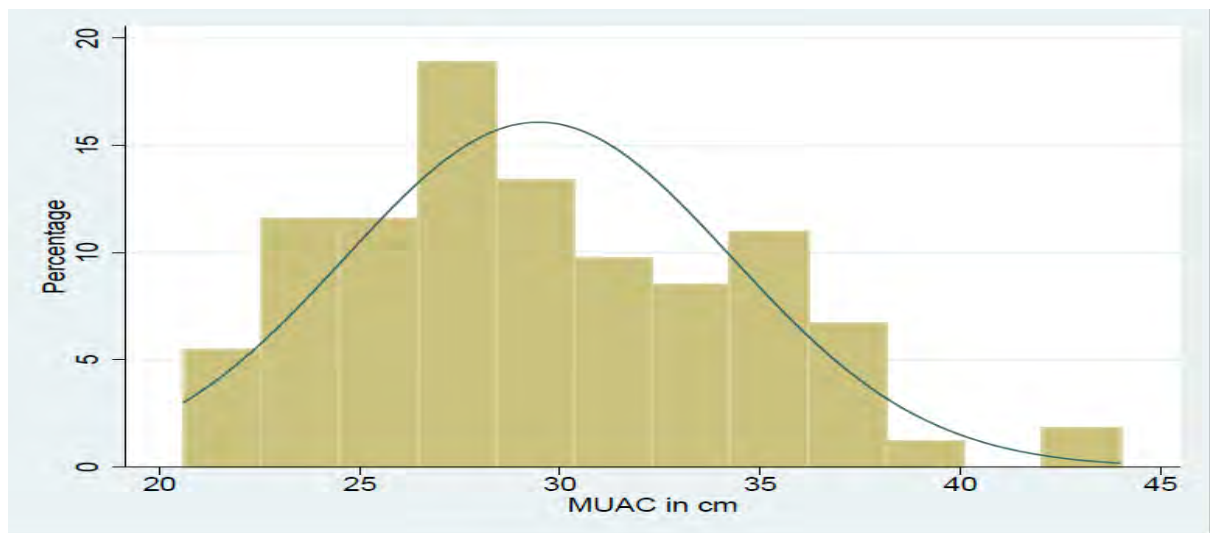


Table 6. Body mass indices (BMI) of the subjects (n=164)

<b>BMI category</b>	<b>N</b>	<b>Percentage</b>
Underweight BMI<18.5kg/m <sup>2</sup>	3	1.8%
Normal weight BMI>18.5-24.9kg/m <sup>2</sup>	54	32.9%
Overweight BMI >25.0-29.9kg/m <sup>2</sup>	53	32.3%
Obese BMI>30.0-39.9kg/m <sup>2</sup>	45	27.4%
Morbidly obese> 40.0kg/m <sup>2</sup>	9	5.4%

The BMI ranged from 16.7 to 48.9 kg/m<sup>2</sup> with a mean BMI calculated at 28.3 ±6.62. The BMI assessment revealed 1.8 % of participants were underweight, 32.9 % fell into normal BMI, 32.3% overweight and 32.9% were obese. Figure2 and table 5 demonstrate the distribution of BMI.

Figure 3. Distribution of Mid Upper Arm Circumference



The mean mid upper arm circumference calculated was 29.4cm ± 4.83cm, with a range of 20.6 to 44cm. MUAC distribution is displayed in Figure 3.

Figure 4. BMI (kg/m<sup>2</sup>) and MUAC (cms) Distribution

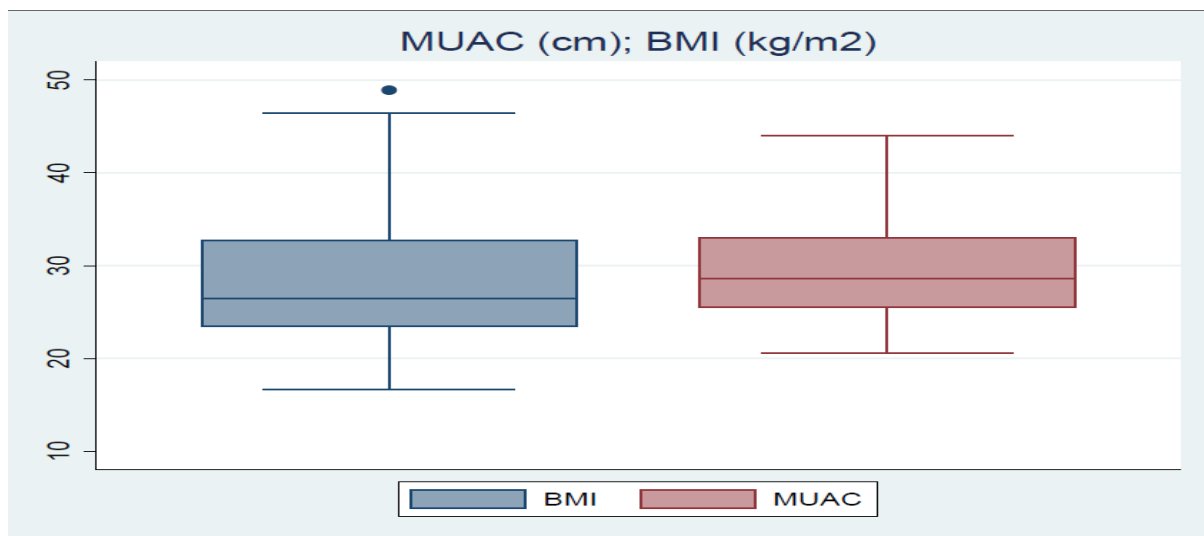
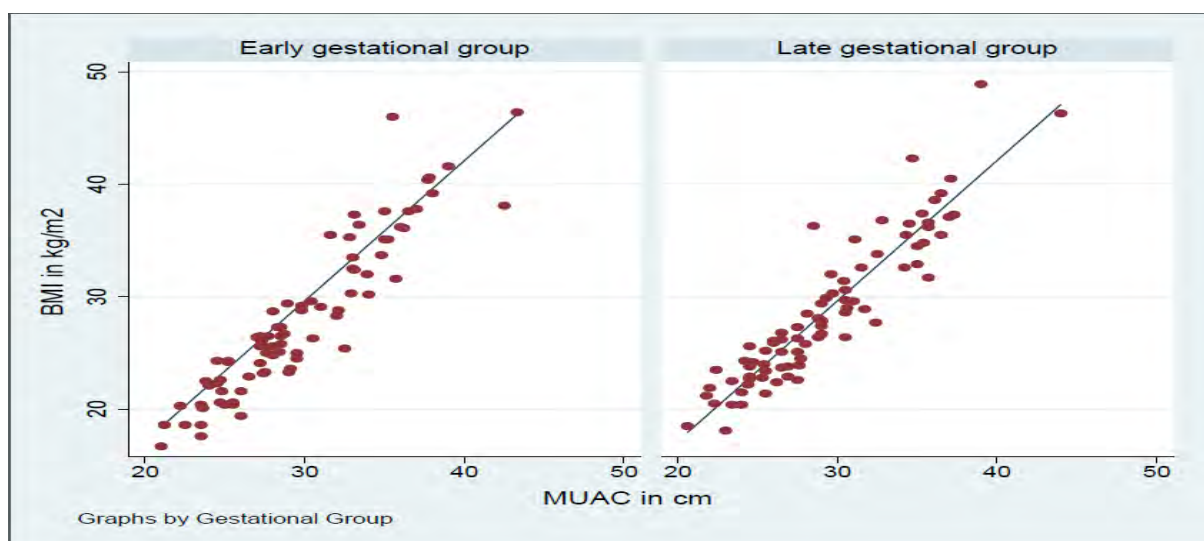


Figure 4 is a whisker plot displaying the distribution of MUAC and BMI.

Figure 5. A comparison between Early gestational Group <20w= EGG and Late gestational group >20w=LGG



There is a strong correlation between body mass index and mid upper arm circumference in pregnancy in patients who book less than 30 weeks as displayed by the scatter plots in Figure 5. The overall correlation was calculated to be 0.92. The correlation between BMI and MUAC for the early gestational group was calculated at 0.93 where as for the late gestational

group, pregnancies >20 weeks it was calculated at 0.92. The correlation for both groups is very strong.

A linear regression on BMI and MUAC was done. It showed that on average, for each unit of MUAC (1cm), BMI increases by 1.27 (kg/m<sup>2</sup>) units. With a p value of less than 0.0001, this represents a very strong statistical significance i.e. the null hypothesis that there is no correlation is rejected and we can state that there is a statistically significant correlation between MUAC and BMI. This simple univariate model explains 0.85 (85%) of the variation in BMI. To account for further variation, the possible role of gestational age in predicting the BMI is tested by the addition of gestational age as another variable making it a multivariate analysis. The regression analysis (Appendix 1 Table 13.) shows that gestational age is also significant in predicting BMI ( $p < 0.0001$ ). However this effect could be different if we use only the two categories of less than 20 (EGG) weeks and more than 20 weeks (LGG). Once again the results are statistically significant (Appendix 1 Table 14.) although as can be expected at a weaker level (p value of 0.002). From this regression analysis the relationship between these three variables can be described mathematically as follows in patients who are less than 20 weeks gestation:

$$\text{BMI prediction} = -10.917 + 1.271 * \text{MUAC}$$

In those patients who are more than 20 weeks the following mathematical calculation can be used:

$$\text{BMI prediction} = -10.917 + 1.271 * \text{MUAC} + 1.2195$$

This can be further interpreted as follows: for every unit change in MUAC, BMI will increase by 1.27 units. Additionally, controlling for MUAC, those patients who are in the late gestational group are predicted to have 1.2195 units of BMI

more than those who are in the early gestational group. This analytical method rests on the assumption that there is a linear relationship between the variables. This was tested by the visual inspection scatter plot displayed in figure 5. Furthermore, in order to use the results in the clinical setting, the cut-off points for different BMI categories were assessed.

Table 7. MUAC cut-off points for different BMI categories

<b>BMI Categories</b>	<b>BMI(kg/m<sup>2</sup>)</b>	<b>MUAC in cms cut off (95% confidence interval)</b>
Underweight	< 18.5	22.8 (CI 22.28-23.31)
Overweight	25.0-29.9	27.1 (CI 26.87-27.51)
Obese	30-39.9	30.57 (CI 30.27-30.86)
Morbidly Obese	>40	37.32 (CI 36.74-37.90)

The regression model (Appendix 1 Table 15.) was used to calculate MUAC cut offs for the different BMI categories. The MUAC cut-off point for obesity was 30.57cm (CI 30.27-30.86), rounded off to 31cm. This had a sensitivity 90.56% (CI 79.34-96.8) and a specificity 93.6% (CI 87.4-97.4), with a PPV of 87.2% (CI 75.5-94.7) and a NPV of 95.4% (CI 89.6-98.4). The cut off for the underweight category is 22.8cm (CI 22.28-23.31). Table 7 demonstrates the MUAC cut-off points for the BMI categories.

Table 8. Specificity and Sensitivity for overweight MUAC cut off

True condition: BMI $\geq 25$ overweight category				
		Present	Absent	Total
Screening results MUAC $\geq 27$	Positive	100	10	110
	Negative	7	47	54
	Total	107	57	164

Table 9. Sensitivity and specificity for obese MUAC cut off

True condition: BMI $> 30$ obese category				
		Present	Absent	Total
Screening results MUAC $\geq 31$	Positive	48	7	55
	Negative	5	104	109
	Total	53	111	164

Table 10. Sensitivity and specificity for morbidly obese MUAC cut off

True condition: BMI $> 40$ morbidly obese category				
		Present	Absent	Total
Screening result MUAC $\geq 37$	Positive	7	5	12
	Negative	2	150	152
	Total	9	155	164

Table 11. Specificity, sensitivity, negative predictive values, positive predictive values for overweight, obese, and morbidly obese BMI categories (gold standard).

	<b>BMI ≥25kg/m<sup>2</sup> MUAC ≥27cm</b>	<b>BMI ≥30kg/m<sup>2</sup> MUAC ≥31cm</b>	<b>BMI ≥40kg/m<sup>2</sup> MUAC ≥37</b>
<b>Sensitivity (%) (CI)</b> TP/ (TP+FN)x100 <u>SCREENING TEST</u>	<b>93.4%</b> <b>(CI 86.9-97.3)</b> 100/(100+7)x100	<b>90.5%</b> <b>(CI 79.3-96.8)</b> 48/(48+5)x100	<b>77.7%</b> <b>(CI 39.9-97.1)</b> 7/(7+2)x100
<b>Specificity (%) (CI)</b> TN/(FP+TN)x100 <u>DIAGNOSTIC TEST</u>	<b>82.4%</b> <b>(CI 70.0-91.2)</b> 47/(10+47)x100	<b>93.6%</b> <b>(CI 87.4-97.4)</b> 104/(7+104)	<b>96.7%</b> <b>(CI 92.6-98.9)</b> 150/(5+150)x100
<b>+Predictive value</b> (%) (CI) TP/(TP+FP)x100 <u>LIKELIHOOD OF</u> <u>CONDITION</u>	<b>90.9%</b> <b>(CI 83.9-95.9)</b> 100/(100+10)x100	<b>87.2%</b> <b>(CI 75.5-94.7)</b> 48/(48+7)x100	<b>58.3%</b> <b>(CI 27.6-84.8)</b> 7/(7+5)x100
<b>- Predictive value</b> (%) (CI) TN/(FN+TN)x100 <u>LOW</u> <u>PROBABILITY OF</u> <u>THE CONDITION</u>	<b>87%</b> <b>(CI 75.0-94.6)</b> 47/(47+7)x100	<b>95.4%</b> <b>(CI 89.6-98.4)</b> 104/(5+104)x100	<b>98.6%</b> <b>(CI 95.3-99.8)</b> 150/(2+150)x100

The MUAC cut off with the highest sensitivity is the cut off for screening overweight patients (MUAC  $\geq 27$ cm). The cut off had a sensitivity of 93.4%. The MUAC cut off for screening for obesity too had a sensitivity of above 90%. However, the sensitivity for the morbidly obese cut off of  $\geq 37$ cm dropped to 77.7%, this group had very low numbers and would need a larger sample size to better assess this cut off. The cut off with best specificity assessing the diagnostic strength of a test was the cut off ( $\geq 37$ cm) for morbidly obese category. The MUAC cut off with the best positive predictive value 90.9% was the cut off ( $\geq 27$ cm) for the overweight category. The cut off with the best negative predictive value assessing the least probability of disease was once again the cut off of  $\geq 37$ cm for the morbidly obese category.

## **Discussion**

As expected there is a strong correlation between BMI and MUAC of 0.92 in pregnant women less than 30 weeks gestation in the Metro West maternity facilities studied. What was indeed surprising was that this strong correlation persisted up to 30 weeks of gestation, disproving our hypothesis that the correlation would be less strong after 20 weeks gestation because of the exponential increase in weight gain. The strong correlation is supported by the study done by S M Cooley on pregnant women in London and Ireland which also found a positive correlation of 0.836;  $p=0.01$  between BMI and MUAC<sup>38</sup>. Similarly this strong correlation between BMI and MUAC was found in the studies by James et al in five African countries<sup>4</sup> and Khadivzedah in Iran<sup>30</sup>. It does however make one wonder if MUAC is a good measure of pre-pregnancy BMI as proposed by many previous studies, why does it correlate up to gestation of 30 weeks in our sampled population. According to Institute of Medicine women should gain approximately 8kg by the 30<sup>th</sup> week<sup>10</sup>. Could this



mean that it actually is not a good predictor of pre-pregnancy BMI, in the population of our study?

Both our data, as well as the study done by S M Cooley et al had a MUAC cut-off point for overweight of 27cm. The MUAC cut-off for obesity in our study was found to 30.57cm (CI 30.27-30.86) using the BMI of 30 as the gold standard for measuring obesity. This was rounded off to 31cm for the practical reasons. This had a sensitivity of 90.5% (CI 79.3-96.8), and a specificity of 93.6% (CI 87.4-97.4), with a PPV of 87.2% (CI 75.5-94.7) and a NPV of 95.4% (CI 89.6-98.4).

The strength or weakness of a test used for screening is verified by calculating the sensitivity and specificity. The sensitivity of a test is its ability to diagnose the disease in those who truly has it, where as the specificity is to correctly identify those in whom the disease is truly absent. A good screening test is one which has a high sensitivity and specificity. Predictive values are determined from sensitivities and specificities. Predictive values looks at the likelihood of outcomes. A PPV looks at the likelihood of an outcome based on a result, where as NPV looks at the likelihood of no outcome. So therefore a test with a high sensitivity, would mean that a person with a negative result is highly unlikely to have the outcome, therefore there would be a greater NPV for the test. On the other hand a test with high specificity would mean that it would be very unlikely for a person with a positive result not to actually have the outcome, hence a high PPV for the test.

Interpreting the results of the MUAC cut off for obesity of 31cm, it was found to have a sensitivity of 90.5%. This means that 90.5% of women with a BMI over 30 kg/m<sup>2</sup> had a MUAC of over 31cm, and that only 9.5% of obese women were not identified by MUAC. Conversely 87.2% of women with a MUAC over

31cm were obese, and 95.4% of women with MUAC under 31cm were not obese. Of note, the Khadivzadeh study also had obese cut-off of 30.5cm for BMI over 29 kg/m<sup>2</sup>.

Our underweight cut off was calculated at 22.8cm (CI 22.28-23.31). The sensitivity, specificity, PPV, NPV was not calculated for the underweight category because of the small number of participants (3) in this category. Table 11 displays the different sensitivities, specificities, NPV and PPV percentages for the other 3 BMI categories. Of note is how the sensitivity of MUAC drops in the morbidly obese group of patients, to 77.7% (CI 39.9-97.1). Okereke et al looked at anthropometric indices for diagnosing obesity in pregnancy in a cross sectional study in Nigeria<sup>25</sup>. He found that MUAC of 33cm and a calf circumference (CC) of 39cm may be a reliable cut off for diagnosing obesity in pregnant women in Nigeria. However just as there have been different MUAC cut offs internationally for under nutrition as previously noted in the literature review: MUAC <18.5 cm (Zimbabwe 2008), <21.0 cm (Burkina Faso, Burundi 2002, DRC 2008, Guinea 2005, Madagascar 2007, Malawi 2007, Mali 2007, Nigeria 2006, Senegal 2008), <22.0 cm (Mozambique 2008), <22.5 cm (Zambia 2009), <23.0 cm (Indonesia 1996) and ≤23 cm (Sri Lanka 2006)<sup>6</sup>; there are most likely different cut offs for measuring obesity as well.

Currently the MUAC being used in the antenatal case records as normal values for MUAC are 23-33cm. If the MUAC is above 33cm, it would warrant referral to a dietician for dietary advice. The systematic review done by Thangaratnam showed that dietary intervention was the most successful for reducing maternal weight gain and pregnancy outcomes, particularly a reduction in risk for preeclampsia<sup>26</sup>. It would also be advisable to screen for gestational diabetes by doing a glucose tolerance test (GTT) at sixteen weeks, and if normal repeat it at 28 weeks. In addition, a referral to a secondary level

institution for further antenatal care and delivery would be indicated. On the opposite end of the scale the cut off for referral to the dietician for nutritional support is a MUAC of less than 23cm. Perhaps the current MUAC cut off for obesity as stipulated by SA antenatal case record of more than 33cm is too high. According to our study the cut off was calculated at 30.57cm, and rounded off to 31cm for practical reasons. Could this imply that we are perhaps missing a group of patients who are at risk, and screening them as normal. Obviously our study was not initially powered to calculate cut offs so a recommendation for further research would be to review the current cut off MUAC values to either validate or dispute them. Our cut off for malnutrition was measured at 22.8cm so rounded off to 23cm, more in keeping with the current MUAC values being used. Despite the fact that nutritional support in malnourished women remains controversial, it would be difficult not to use the opportunity of pregnancy to get them into a nutritional programme to improve their health. This would be similar to how we use antenatal care as an opportunity to test all women for HIV, and initiate lifelong antiretroviral therapy.

The BMI distribution of the population of pregnant women sampled also is in agreement with the study done by Puoane et al in 2002, stating that 56.6% of females aged 15yrs and above were found to be overweight or obese<sup>22</sup>. Our percentage for overweight and obesity in this group is an alarming 65.1%, most likely displaying the increasing concern of the obesity epidemic. Figure 1 displays the BMI distribution, and what is indeed evident from the bar chart is the second peak in the obese category. The rising prevalence of obesity has major implications for both the mother and the fetus. The maternal risks include an increased risk for gestational diabetes and hypertension, caesarean section, veno-thromboembolism, postpartum haemorrhage and sepsis. For the

fetus, there is an increased risk of miscarriage, macrosomia, stillbirth and neural tube defects. The current study did not follow up subjects to assess outcomes, but this would be an interesting suggestion for future studies. A retrospective cross sectional study was done by Basu J et al on obesity and its outcomes on pregnant women in South Africa<sup>46</sup>. They looked at 767 women and found that 44% were classified into the obese or morbidly obese categories according WHO BMI classification. They too found that urinary tract infection, failed induction of labour as well as gestational diabetes were all more common in the morbidly obese category<sup>46</sup>. The percentage of women who were found to be obese or morbidly obese in our study was not as high as the Basu et al study, however still an alarming 32.8% fell into this category.

### **Limitations**

The fact that there was not a standardised way to calculate the exact gestational age was definitely a limitation. An ultrasound machine was only available for approximately half of the participants; for the other half gestational age was calculated clinically using the symphysis fundal height at booking and taking their dates into consideration.

Although a strength of the study was the single provider doing all the measurements (thus enabling consistency in which to test the correlation of BMI and MUAC), this could also be seen as a limitation in that assessment of reproducibility of the MUAC measurements was not done. All the MUAC measurements were taken by one person the principal investigator, and this was never tested to see if the same result would be obtained by another examiner.

No social data or medical history was collected from the patients. Smoking, HIV status, employment, partner stressors, ethnicity, and medical history, all of these can affect the BMI.

The mean gestation was nineteen weeks. The cut-off of thirty weeks gestation was quite limiting. In retrospect, it might have been advisable to have included everyone up to forty weeks when comparing patients who booked less than twenty and those who were more than twenty weeks, as the majority of weight gain occurs in the third trimester.

Recommendations for future studies on this topic would be to:

- (a) Compare MUAC and BMI in pregnant women up to forty weeks
- (b) Assess pregnancy outcomes in women assessed by the two MUAC cut off values to be underweight or obese patients
- (c) To verify the MUAC cut offs of MUAC for underweight (23cms) and obesity (31cms) as found in this study and
- (d) Assess the reproducibility of MUAC measurements performed by different providers.

### **Conclusion**

The MUAC correlates strongly with BMI in pregnancy up to a gestation of thirty weeks in women in Metro West maternity services.

In a low resource settings, the simpler MUAC measurement to assess nutritional status and screen women who are at risk for potential adverse pregnancy outcomes could reliably be substituted for BMI estimation. This would eliminate the need for calibrated weight scales, height charts, as well as calculations for BMI.

Further research on implementation of MUAC and correlating MUAC cut offs with pregnancy outcomes is indicated.

## **References**

1. South Africa. National department of health. Republic of South Africa. Fourth Edition 2015.Guidelines for maternity care in South Africa: A manual for clinics, community health centres and district hospitals.Government Publisher.
2. South Africa. Packages of care. Western Cape Department of Health. February 2009
3. De Onis M, Yip R, Mei Z. The development of MUAC-for-age reference data recommended by a WHO Expert Committee. Bulletin of the World Health Organization. 1997; 75 (1):11-18
4. James W P T, Mascie-Taylor G C N, Norgan N G, Bistran B R, Shetty P S, Ferro-Luzzi A . The value of arm circumference measurements in assessing chronic energy deficiency in third world adults. European Journal of Clinical Nutrition. 1994; 48:883-894
5. Collins S. Using middle upper arm circumference to assess severe adult malnutrition during famine. JAMA. 1996; 276(5):391-395
6. Ververs M, Antierens A, Sackl A, Staderini N, Captier V. Which anthropometric indicators identify a pregnant woman as acutely malnourished and predict adverse birth outcomes in a humanitarian context? PLOS curr. 2013 June; 5:PMC 3682760
7. Food and Nutrition Technical Assistance. Nutrition Assessment Counselling and Support: Users guide 2013. Module 2. Nutrition, assessment and classification.
8. Kruger H S. Maternal anthropometry and pregnancy outcomes: a proposal for the monitoring of pregnancy weight gain in outpatient clinics in South Africa. Curationis. 2005; 28(4): 40-49
9. Fattah C, Farah N, Barry S, O'Connor N, Stuart B, Turner M J. The measurement of maternal adiposity. Journal of Obstetrics and Gynaecology. 2009; 29(8):686-689
- 10.Bhurosy T, Jeewon R. Pitfalls of using BMI in assessment of obesity risk. Current Research in Nutrition and Food Science. 2013; 1:71-76
- 11.Cox J T, Phelan T, MS, RD, LN. Nutrition during pregnancy. Journal of Obstetrics and Gynaecology Clinics of North America. 2008; 35: 369-383
- 12.Barker J P. Maternal nutrition, fetal nutrition, and disease in later life. Nutrition. 1997; 13:807-813

13. Roseboom T, de Rooij S, Painter R. The Dutch famine and its long term consequences for adult health. *Early human development*. 2006; 82: 485-491
14. Verhoeff F, Brabin B, Chimsuku L, Kazembe P, Broadhead R. An analysis of the determinants of anaemia in pregnant women rural Malawi ; a basis for action. *Annals of Tropical Medicine and Parasitology*. 1999 March; 93(2): 119-133
15. Charles A M, Campbell-Stennet D, Yatich N, Jolly P E. Predictors of anaemia among pregnant women in Westmoreland Jamaica. *Health care of women Int*. 2010; 31(7):585-598
16. Libombo A, Folgosa E, Bergstrom S. Risk factors in puerperal endometritis-myometritis. *Gynaecol Obstet Inves*. 1994; 38: 198-205
17. Christian P, Katz J, Wu L, Kimbrough-Pradhan E, Khatri S, LeClerq S, et al. Risk factors for pregnancy related mortality: A prospective study in rural Nepal. *Public Health*. 2008 February; 122(2):161-172
18. Ceesay S M, Prentice M, Cole T, Foord F, Poskitt E, Weaver L, et al. Effects on birth weight and perinatal mortality of maternal dietary supplements in rural Gambia: 5 year randomised controlled trial. *British medical journal*. 1997; 315:786
19. Villar J, Rivera J. Nutritional supplementation during two consecutive pregnancies and the interim lactation period: effect on birth weight. *Paediatrics*. 1988; 81(1):51-57
20. Bhutta Z A, Darmstadt G L, Hasan B S, Haws R A. Community-Based Interventions for Improving Perinatal and Neonatal Health Outcomes in Developing Countries: A Review of the Evidence. *Paediatrics*. 2005 February; 115(2): 519-617
21. Bhutta Z A, Das J K, Rizvi A, Gaffey M F, Walker N, Horton S, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet*. 2013; 382: 452-477
22. Puoane T, Steyn K, Bradshaw D, Laubsher R, Fourie J, Lambert V et al. Obesity in South Africa: The South African and Demographic health survey. *Obesity Research*. 2002; 10:1038-48
23. Dixit A, Girling J C. Obesity and pregnancy. *Journal of Obstetrics and Gynaecology*. 2008 January; 28(1):14;23



24. Nieuwoudt M, van der Merwe J L, Harvey J, Hall D R. Pregnancy outcomes in super-obese women - an even bigger problem? A prospective cohort study. *South African Journal of Obstetrics and Gynaecology*. 2014; 20(2):54-59
25. Okereke C E, Anyaehie U B, Dim C, Iyare E, Nwagha U. Evaluation of some anthropometric indices for the diagnosis of obesity in pregnancy. *African Health Sciences*. 2013; 13(4): 1034-1040.
26. Thangaratinam S, Rogozinska E, Jolly K, Glinkowski, Roseboom T, Tomlinson J, et al. The effects of interventions in pregnancy on maternal weight and obstetric outcomes; a meta-analysis of randomised evidence. *British medical journal*. 2012 July; 344: e2088  
doi:10.1136/bmj.e2088
27. Mahomed K, Williams M, Woelk G, Jenkins-Woelk L, Mudzamiri S, Longstaff L, et al. Risk factors for pre-eclampsia among Zimbabwean women: maternal arm circumference and other anthropometric measures of obesity. *Paediatric and perinatal epidemiology*. 1998; 12: 253-262
28. Ogbonna C, Woelk G, Ning Y, Mudzamiri S, Mohamed K, Williams M. Maternal mid-arm circumference and other anthropometric measures of adiposity in relation to infant birth size among Zimbabwean women. *Acta Obstetrica et Gynecologica*. 2007; 86:26-32
29. Hediger M L, Luke B, van de Ven C, Nugent C. Mid upper arm circumference (MUAC) changes in late pregnancy predict fetal growth in twins. *Twin research and human genetics*. 2005; 8(3):267-270
30. Khadivzadeh T. Mid upper arm and calf circumferences as indicators of nutritional status in women of reproductive age. *Eastern Mediterranean health journal* 2002; 8(4/5): 612-618
31. Abrams B, Altman S, Pickett K. Pregnancy weight gain still controversial. *American Journal of clinical nutrition*. 2000; 71(suppl): 1233s-41s
32. Weight gain during pregnancy. Committee Opinion No. 548. *American Obstetricians and Gynecologists*. *Obstet Gynecol* 2013; 121:210-2
33. Bhattacharya S, Campbell D, Liston W, Bhattacharya S. Effect of Body Mass Index on pregnancy outcomes in nulliparous women delivering singleton babies. *BMC Public Health*. 2007; 7: 168
34. Sebire N, Jolly M, Harris J, Regan L, Robinson S. Is maternal underweight really a risk factor for adverse pregnancy outcome? A population-based

- study in London. *British Journal of Obstetrics and Gynaecology*. 2001; 108: 61-66
35. Cnattingius S, Bergstrom R, Lipworth L, Kramer M. Prepregnancy weight and the risk of adverse pregnancy outcome. *The New England Journal of Medicine*. 1998; 338(3):147-152
  36. Lopez L B, Calvo E, Poy M, del Valle Balmaceda Y, Camera K. Changes in skinfolds and mid-upper arm circumference during pregnancy in Argentine women. *Maternal and Child Nutrition*. 2011; 7:253-262
  37. Liljestrand J, Bergstrom S. Antenatal Nutritional Assessment: The Value of Upper Arm Circumference. *Gynecol Obstet Invest*. 1991; 32:81-83
  38. Cooley S M, Donnelly J, Walsh T, Durnea U, Rodeck C, Hindmarsh P, et al. The relationship between body mass index and mid-arm circumference in a pregnant population. *Journal of Obstetrics and Gynaecology*. 2011 Oct; 31: 594-596
  39. Ricalde A, Velasquez-Melendez G, d'A A C. Mid-upper arm circumference in pregnant women and its relation to birth weight. *Revista de Saude Publica*. 1998 April; 32(2):488-94
  40. <http://en.wikipedia.org/wiki/Gugulethu>
  41. [http://en.wikipedia.org/wiki/Retreat,\\_Cape\\_Town](http://en.wikipedia.org/wiki/Retreat,_Cape_Town)
  42. <http://en.wikipedia.org/wiki/Masiphumelele>
  43. [http://en.wikipedia.org/wiki/Mitchells\\_Plain](http://en.wikipedia.org/wiki/Mitchells_Plain)
  44. [http://en.wikipedia.org/wiki/Hanover\\_Park,\\_Cape\\_Town](http://en.wikipedia.org/wiki/Hanover_Park,_Cape_Town)
  45. <http://www.openepi.com/oe2.3/SampleSize/SSCohort.htm>  
Source file last modified on 09/21/2010 04:10:31
  46. Basu J, Jeketera C, Basu D. Obesity and its outcomes among pregnant South African women. *International Journal of Gynecology and Obstetrics*. 2010; 110:101-104

## Appendix 1

Table 12. Linear regression of BMI MUAC

Source	SS	df	MS	Number of obs = 164		
Model	6111.5678	1	6111.5678	F( 1, 162) = 955.84		
Residual	1035.81269	162	6.39390547	Prob > F = 0.0000		
				R-squared = 0.8551		
				Adj R-squared = 0.8542		
Total	7147.38049	163	43.84896	Root MSE = 2.5286		

BMI	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
MUAC	1.265752	.0409407	30.92	0.000	1.184906	1.346598
_cons	-8.931511	1.222356	-7.31	0.000	-11.34532	-6.517705

Table 13. Regression analysis of BMI MUAC and gestational age

Source	SS	df	MS	Number of obs = 164		
Model	6196.13684	2	3098.06842	F( 2, 161) = 524.35		
Residual	951.243644	161	5.90834561	Prob > F = 0.0000		
				R-squared = 0.8669		
				Adj R-squared = 0.8653		
Total	7147.38049	163	43.84896	Root MSE = 2.4307		

BMI	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
MUAC	1.267651	.0393587	32.21	0.000	1.189925	1.345377
GESTDEC	.102919	.0272034	3.78	0.000	.0491976	.1566405
_cons	-10.95279	1.290784	-8.49	0.000	-13.50185	-8.403744

Table 14. Regression analysis of BMI MUAC and Gest group01 (EGGvsLGG)

Source	SS	df	MS	Number of obs = 164		
Model	6172.43496	2	3086.21748	F( 2, 161) = 509.65		
Residual	974.94553	161	6.0555623	Prob > F = 0.0000		
				R-squared = 0.8636		
				Adj R-squared = 0.8619		
Total	7147.38049	163	43.84896	Root MSE = 2.4608		

BMI	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
MUAC	1.271059	.0398779	31.87	0.000	1.192308	1.34981
gestgroup01	1.219502	.3846522	3.17	0.002	.4598876	1.979116
_cons	-9.697626	1.213871	-7.99	0.000	-12.09479	-7.300464

Table 15. Regression of MUAC BMI

Source	SS	df	MS	Number of obs = 164		
Model	3261.82746	1	3261.82746	F( 1, 162) = 955.84		
Residual	552.82742	162	3.41251494	Prob > F = 0.0000		
Total	3814.65488	163	23.4027907	R-squared = 0.8551		
				Adj R-squared = 0.8542		
				Root MSE = 1.8473		

MUAC	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
BMI	.6755493	.0218506	30.92	0.000	.6324005	.7186981
_cons	10.30375	.6363241	16.19	0.000	9.04719	11.56031

Table 16. Predictive margins of MUAC at BMI values

Expression : Linear prediction, predict()

1.\_at : BMI = 30  
 2.\_at : BMI = 35  
 3.\_at : BMI = 40  
 4.\_at : BMI = 18.5

	Delta-method		t	P> t	[95% Conf. Interval]	
	Margin	Std. Err.				
_at						
1	30.57608	.1447217	211.28	0.000	30.29028	30.86187
2	33.97169	.1993071	170.45	0.000	33.57809	34.36528
3	37.36729	.2849576	131.13	0.000	36.80456	37.93003
4	22.76617	.2527726	90.07	0.000	22.267	23.26535

## Appendix 2

	Folder number	Age	Gravidity	Parity	Weight	Height	BMI	MUAC	Gestational age
1									
2									
3									
4									
5									
6									
7									
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